DRAFT REPORT
APPENDIX E-3-1
LABORATORY SCREENING TEST FOR SURROGATE COMPOUNDS CIBA-GEIGY SUPERFUND SITE TOMS RIVER, NEW JERSEY

SUBMITTED BY

Ciba

SUBMITTED TO

EPA

United States Environmental Protection Agency

PREPARED BY

Ciba Specialty Chemicals
Corporate Remediation
Toms River, New Jersey
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1.0 INTRODUCTION

The Ciba-Geigy Superfund Site (Site) located in Toms River, New Jersey has several source areas impacted with chlorinated and non-chlorinated organic chemicals due to past industrial operations, wastewater treatment, and disposal practices. This Site is owned by Ciba Specialty Chemicals (Ciba). The U. S. Environmental Protection Agency's (USEPA) "Final Source Control Remedial Investigation Report" identifies twenty potential contaminant source areas at the Site (UESPA, 1994). Addressing these source areas, collectively known as Operable Unit 2 (OU2), is the goal of the OU2 Feasibility Study. Remedial activities to address the Site-related contamination are regulated under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended by the Superfund Amendments Reauthorization Act of 1986 (SARA). The site was placed on the CERCLA National Priorities List (NPL) in 1983.

Technology selection is a significant part of the Feasibility Study (FS) Report. This report describes the laboratory testing involved in technology evaluation for surrogate compounds. Surrogates are chemicals that represent classes of compounds used previously in the dye manufacturing at the Site. Surrogates are not part of the target contaminants listed for this Site. An understanding of these non-target compounds susceptibility to biodegradation was needed. Therefore, Ciba conducted a laboratory screening test to evaluate the biodegradation potential of the surrogate compounds. The details of the surrogates screening test are provided in the Technical Memorandum I submitted to the Agency in September 1998, along with the Composting Treatability Study Work Plan (Ciba, 1988). The three surrogates selected for the screening test are:

- 2-Aminoanthraquinone
- Aminoazobenzene-4-sulfonic acid
- 7-Amino-1-naphthol-3-sulfonic acid

Typically, these three surrogates are representative of the intermediates used in the manufacture of dyes. The surrogates screening test was started in August of 1998 and proceeded until February 1999, allowing approximately 7 months of treatment time. This report provides the technical details and results of the surrogates screening test.

2.0 SCOPE OF WORK

The surrogate screening test was conducted in laboratory microcosms using the Site groundwater and soil. The three surrogates chosen for the screening test are 2-aminoanthraquinone, and aminoazobenzene-4-sulfonic acid, and 7-amino-1-naphthol-3-sulfonic acid. The objectives of testing are the following:

- Determine the degradation potential of surrogate compounds and evaluate if the degradation is due to biological or chemical process;
- Monitor degradation of surrogates in both the aqueous and soil phases;
- Calculate the degradation rates and half-lives of the surrogate compounds; and
- Monitor relevant biodegradation parameters (such as pH changes and nutrient consumption) during the surrogate decomposition.

The experimental procedures and results of the testing are discussed in Section 3.0 and Section 4.0, respectively.

3.0 EXPERIMENTAL PROCEDURES

The microcosm testing evaluated aerobic biodegradation potential of surrogate compounds by microorganisms indigenous to the Site. This section describes the experimental design, monitoring parameters, sampling and analytical methods, and soil and groundwater used to evaluate degradation of the surrogates.

3.1 INITIAL CHARACTERIZATION OF GROUNDWATER AND SOIL

Groundwater and soil were collected from the Biopilot Cell at the Site for use in the screening test. Prior to use in the test, the groundwater and soil were characterized in duplicate for the parameters listed below:

- pH;
- Ammonia nitrogen;
- Anions (nitrate, nitrite, orthophosphate, sulfate, chloride);
- Cations (sodium, potassium, calcium, magnesium, iron and manganese);
- Total organic carbon;
- Microbial density; and
- VOCs.

These parameters were considered to provide baseline information on the status of the nutrients, microbial density, and groundwater chemistry. The analytical methods for the parameters are listed in Table 3.1. The parameters were analyzed either in-house or contracted to an outside analytical laboratory.

3.2 MICROCOSM TESTING

The objective of laboratory-scale testing was to determine the feasibility of biodegradation of surrogate compounds by microorganisms indigenous to the Site. An experiment was conducted using batch microcosms that consisted of 160-ml capacity clean, sterile, glass serum bottles. Approximately 60 mL of groundwater and 25 g of soil were added to each serum bottle. After the addition of groundwater and soil, the bottles were closed with Teflon-lined butyl rubber stoppers and crimped with aluminum seals.

The microcosms were amended with individual surrogate compounds (2-aminoanthraquinone, aminoazobenzene-4-sulfonic acid or 7-amino-1-naphthol-3-sulfonic acid) or a mixture of three surrogates (2-aminoanthraquinone + aminoazobenzene-4-sulfonic acid + 7-amino-1-naphthol-3-sulfonic acid). These treatment variations are described in Table 3.2. 2-Aminoanthraquinone is poorly soluble in water, and was added to microcosms to provide a soil concentration of 60 mg/kg. Aminoazobenzene-4-sulfonic acid and 7-amino-1-naphthol-3-sulfonic acid are fairly soluble in water, and were added to microcosms to provide a groundwater concentration of 20 mg/L. Sodium azide-amended control microcosms were maintained to inhibit the biological activity and monitor the abiotic loss, if any. Sodium azide was added to provide a concentration of 700 mg/L. Nutrients in the form of urea and ammonium phosphate were added to all microcosms to support biodegradation. The nutrients were added to the groundwater to provide a concentration of 30 mg/L of nitrogen and 27 mg/L of phosphorus. The bottles were incubated in dark at room temperature and mixed periodically on a shaker. Approximately 80-mL air headspace was maintained in the microcosms to provide air required for biodegradation.

3.3 SAMPLING AND ANALYSIS

The testing was carried out for approximately 7 months and microcosms were sampled at 0, 0.4, 1.1, 2.2, 3.3, 4.9, and 6.5 months for surrogate analysis. Destructive sampling was performed that involved the extraction of entire contents of the bottle. Soil and aqueous fractions were separated and analyzed separately for the surrogate compounds. Sampling for nutrient and bacteria was performed at 5.5 months and compared with initial characterization data. The following parameters were analyzed in aqueous phase and solid phase:

Liquid Phase:

- pH;
- Ammonia nitrogen;
- Anions (nitrate, nitrite, orthophosphate, sulfate, chloride);
- Total organic carbon;
- 2-Aminoanthraquinone;
- Aminoazobenzene-4-sulfonic acid; and
- 7-Amino-1-naphthol-3-sulfonic acid.

Soil Phase:

- Microbial density;
- 2-Aminoanthraquinone;
- Aminoazobenzene-4-sulfonic acid; and
- 7-Amino-1-naphthol-3-sulfonic acid.

The methods for the above parameters are listed in Table 3.1. Analysis of these parameters provided information on the changes in concentration of surrogate compounds with time and nature of biological activity (changes in the microbial population, nutrient and pH conditions) during the testing. The parameters were either analyzed in-house or contracted to an outside analytical laboratory.

4.0 RESULTS AND DATA EVALUATION

This section describes the groundwater and soil characterization data used in the microcosm study, biodegradation results, and parameters that impact biodegradation (nutrients and microorganisms). The data obtained during the microcosm testing was evaluated to determine the mechanism of surrogate degradation (abiotic or biological process). The results are presented and discussed in Sections 4.1 through 4.4.

4.1 GROUNDWATER AND SOIL CHARACTERIZATION

The groundwater and soil were characterized previously for VOC, nutrient, and other parameters in the chlorobenzenes screening test (see Technical Memorandum - III Report). The same data are used in the surrogate screening test, since groundwater and soil were collected from the same location (Biopilot Cell). The analytical data on organic and inorganic chemicals in the groundwater and soil are summarized in Table 4.1.

The groundwater collected from the Biopilot Cell did not contain significant amount of nitrogen and phosphorus. The Total Kjeldahl Nitrogen (TKN) and orthophosphate were below the method detection limits, while ammonia nitrogen and nitrate nitrogen were low at 0.4 mg/L and 5 mg/L, respectively. The cation (calcium, magnesium, potassium, and sodium) concentration in groundwater was 390 mg/L. The TOC concentration in groundwater was 35 mg/L, while in soil it was at 1,545 mg/kg. The chloride level in groundwater was slightly high at 600 mg/L, due to *in-situ* dechlorination activity occurring in the Biopilot Cell. Microbial enumeration revealed the total heterotrophic bacterial count in the range of 10^3 to 10^4 colony forming units (CFUs)/g.

With respect to VOC, the groundwater typically contained chlorinated chemicals from tens of parts per billion (ppb) to hundreds of ppb (Table 4.1). The only compound with concentration in parts per million (ppm) was 1,2,4-TCB (1.33 mg/L)

4.2 MICROCOSM RESULTS

The degradation of surrogate compounds was monitored separately in both the soil and aqueous fractions. The results on biodegradation of the three surrogates (2-

aminoanthraquinone, 7-amino-1-naphthol-3-sulfonic acid, and aminoazobenzene-4-sulfonic acid) are discussed separately in Sections 4.2.1 through 4.2.3.

4.2.1 DEGRADATION OF 2-AMINOANTHRAQUINONE

The data obtained from the microcosm testing of 2-aminoanthraquinone is presented in Table 4.2 and illustrated in Figure 4.1. The surrogate testing was performed individually and in presence of two additional surrogates. Since 2-aminoanthraquinone is poorly soluble in water, most of this compound was recovered from the soil fraction. The concentration in the aqueous phase was mostly below the method detection limit (Table 4.2).

When tested individually, the concentration of 2-aminoanthraquinone in active microcosms declined from approximately 62 mg/kg to below the method detection limit, in about 2 months of testing (Table 4.2). No appreciable lag was observed, and about 50 percent of the compound was lost within the first sampling interval at 15 days. This decline in 2-aminoanthraquinone concentration was due to biological process, but not chemical or absorption process, since no appreciable decline occurred in sodium azide-treated poisoned control. The concentration of 2-aminoanthraquinone in control was steady and ranged between 47 and 65 mg/kg during 2-month treatment period. A high recovery of 97 mg/kg for the last sampling point (4.9 months) is due to sampling variation (Figure 4.1).

A similar degradation trend was observed when 2-aminoanthraquinone was present as a mixture along with two other surrogates (7-amino-1-naphthol-3-sulfonic acid and aminoazobenzene-4-sulfonic acid). The concentration decreased from 66 mg/kg to below the method detection limit within one month of treatment (Table 4.2). Initially (during first month), the degradation of 2-aminoanthraquinone was slightly faster in presence of other two surrogates, compared to when present alone (Table 4.2). This is evident from a decline in concentration from 66 mg/kg to below detection limit (>99 percent reduction) in the mixture, compared to a decline from 62 mg/kg to 27 mg/kg (56 percent reduction) when present alone. The degradation was biological, since even in the presence of mixture of surrogates, the concentration of 2-aminoanthraquinone in control treatment did not decline (varied between 43 and 74 mg/kg).

4.2.2 DEGRADATION OF AMINOAZOBENZENE-4-SULFONIC ACID

The data obtained from microcosm testing of aminoazobenzene-4-sulfonic acid is presented in Table 4.3 and shown in Figure 4.2. The surrogate testing was performed individually and in presence of two additional surrogates. Since aminoazobenzene-4-sulfonic acid is fairly soluble in water, most of this compound was recovered from the aqueous fraction than from soil fraction. The concentration in the soil fraction was low and ranged between 2 and 4 mg/kg (Table 4.3).

When tested individually, the concentration of aminoazobenzene-4-sulfonic acid in active microcosm declined from approximately 20 mg/L to 8 mg/L after 6.5 months of treatment (Table 4.3). The decline was gradual with approximately 39 percent loss during the first three months and about 33 percent during the next 3 months. The loss of aminoazobenzene-4-sulfonic acid from the water fraction was not simply due to adsorption on to the soil, since this surrogate was recovered only in small amounts from the soil fraction. In fact, the decline was largely due to biological process, since similar concentration decline was not observed in sodium azide-treated poisoned control (ranged between 17 and 20 mg/L). The concentration reduction of aminoazobenzene-4-sulfonic acid in active microcosms was approximately 60 percent, compared to a reduction of only 8 percent in control microcosms, after 6.5 months of treatment (Figure 4.2).

The presence of other two surrogates (7-amino-1-naphthol-3-sulfonic acid and 2-aminoanthraquinone) did not alter the degradation trend of aminoazobenzene-4-sulfonic acid. The concentration reduction for aminoazobenzene-4-sulfonic acid, when present alone and in a mixture, was approximately 59 percent and 52 percent, respectively (Table 4.3). This surrogate degradation in presence of additional two surrogates was due to microorganisms, since the concentration remained almost constant at 16 to 20 mg/L in the poisoned control.

4.2.3 DEGRADATION OF 7-AMINO-1-NAPHTHOL-3-SULFONIC ACID

The data obtained from microcosm testing of 7-amino-1-naphthol-3-sulfonic acid is presented in Table 4.4 and illustrated in Figure 4.3. The surrogate testing was performed individually and in presence of two additional surrogates. Since 7-amino-1-naphthol-3-sulfonic acid is water-soluble, most of this compound was recovered from the aqueous

fraction than from soil fraction. The concentration in the soil fraction was low (<0.7 mg/kg) (Table 4.4).

When tested individually, the concentration of 7-amino-1-naphthol-3-sulfonic acid in active microcosms declined from approximately 16 mg/L to below the method detection limit in less than 2 weeks of treatment (Table 4.4). But, during the corresponding period, the concentration decreased from 17 mg/L to less than 4 mg/L, in the control microcosms. The percent degradation in active and control microcosms was >99.5 percent and 79 percent, respectively. The loss of 7-amino-1-naphthol-3-sulfonic acid even from the control microcosms indicated that the degradation of this compound was primarily due to abiotic process, with very little contribution by biological process.

The degradation trend of 7-amino-1-naphthol-3-sulfonic acid was similar in the presence of other two surrogates (2-aminoanthraquinone and aminoazobenzene-4-sulfonic acid) (Table 4.4). The loss of 7-amino-1-naphthol-3-sulfonic acid in the active and control microcosms was 86 percent and 59, respectively after 2 weeks treatment. However, in one month, it was degraded by greater than 99.5 percent in both control and active microcosms. These results indicated that the loss of 7-amino-1-naphthol-3-sulfonic acid in presence of additional two surrogates was primarily due to abiotic process, with very little biodegradation.

4.3 DEGRADATION RATES AND HALF-LIVES

The microcosm results were used to calculate the degradation rates and half-lives for three surrogate compounds. The degradation rate was calculated from the change in concentration with time using a first order rate equation and half-lives were calculated from the estimated rates. The results on rates and half-lives are presented in Table 4.5.

As expected, the degradation rates were greater in active compared to control treatment for 2-aminoanthraquinone and aminoazobenzene-4-sulfonic acid. The rate for 2-anthraquinone was 0.08/month in the control microcosms, compared to 3.19/month in the active microcosms. Similarly, the rate for aminoazobenzene-4-sulfonic acid was 0.016/month in the control compared to 0.126/month in the active treatment.

The estimated half-life for 2-aminoanthraquinone and aminoazobenzene-4-sulfonic acid was 0.2 and 5.4 months, respectively for the active treatment, and 8.3 and 43 months, respectively for the control treatment. This data supported the importance of microorganisms in the degradation process. In contrast, in microcosms amended with 7-amino-1-naphthol-3-sulfonic acid, the degradation rate was similar in both control and active treatment with a half-life ranging from 5 to 7 days. The low half-live even in the control treatment was due to the chemical instability of this surrogate compound rather than biodegradation.

4.4 NUTRIENT AND MICROBIAL CHARACTERIZATION

The parameters relevant to biodegradation were monitored at the start and near completion of the testing. These included pH, nutrient, sulfate, chloride, and microbial population. These results are shown in Table 4.6.

The optimal pH for bioremediation is generally accepted to be within the range of 6 to 8. A pH outside this range may reduce microbial metabolism and biodegradation. The pH remained near neutral during the treatment period.

Nutrients (ammonia nitrogen, nitrate nitrogen, orthophosphate, and TOC) are necessary to support microbial degradation. Nutrient addition becomes necessary for successful bioremediation when their concentrations are severely limited. The groundwater used in the testing was limiting in nutrient and therefore ammonium phosphate and urea were added to the microcosms to provide a concentration of 30 mg/L of nitrogen and 27 mg/L of phosphorus. Ammonia-nitrogen was generally high in the control and low in active microcosms, revealing the utilization of nitrogen by microorganisms during biodegradation. At the end of treatment, ammonia nitrogen averaged 35 mg/L in the control treatments, compared to an average of 3 mg/L in the active treatments (Table 4.6). A similar trend was observed with TOC, where the concentration ranged between 35 and 39 mg/L in the control microcosms, and between 19 and 24 mg/L in the active microcosms (Table 4.6). The consumption of nitrogen and carbon indicated optimum microbial activity to be occurring in these microcosms.

The complete mineralization of sulfonate-containing surrogates is expected to increase sulfate concentration. But, no significant increase in sulfate concentration was observed in

the active treatments. After 5.5 months of treatment, the sulfate concentration ranged between 261 and 270 mg/L in the control microcosms and between 270 and 287 mg/L in the active microcosms (Table 4.6). Also, a decrease in sulfate concentration was not observed. A decline in sulfate concentration would indicate anaerobic conditions during the treatment, since sulfate can serve as an electron acceptor and substitute for oxygen. With respect to chloride, its concentration did not increase during treatment, since chlorinated chemicals were not present in significant amounts in the groundwater used in the microcosm testing (Table 4.6).

Microbial population (heterotrophic bacteria) were grown on the Trypic-Soy agar medium and enumerated by the spread plate technique. Microbial population was enumerated at the start and after completion of the treatment. The results are presented in Table 4.6. The total heterotrophic bacteria count was mostly in the range of 10^3 to 10^4 CFUs/g during 5.5 months of treatment (Table 4.6).

5.0 SUMMARY

The surrogate screening testing was conducted in laboratory microcosms using the Site groundwater and soil for a period of approximately 6.5 months. The results of the testing are summarized below:

- The soil microorganisms indigenous to the Site were capable of degrading two of the three surrogate compounds tested. The degradation of 2-aminoanthraquinone and aminoazobenzene-4-sulfonic acid was due to microorganisms, but the breakdown of 7-amino-1-naphthol-3-sulfonic acid was largely due to abiotic (chemical) process.

- The biodegradation of 2-aminoantraquinione was significantly greater (>99 percent reduction in 2 months) than aminoazobenzene-4-sulfonic acid (60 percent in 6.5 months).

- The half-live for 2-aminoantraquinione and aminoazobenzene-4-sulfonic acid was 0.2 months and 5.4 months, respectively.

- A greater degradation rate and low half-life (5 days) were observed for 7-amino-1-naphthol-3-sulfonic acid, but the transformation is due to the abiotic (chemical) process rather than biological process.

- The biodegradation trend for 2-aminoanthraquinone and aminoazobenzene-4-sulfonic acid in the absence and presence of other surrogate compounds remained the same.

The above results indicated that all three surrogate compound tested were are degraded in the soil and groundwater matrix existing at the Site. The decomposition of two surrogates (for 2-aminoanthraquinone and aminoazobenzene-4-sulfonic acid) was due to microorganisms that are indigenous to the Site, while the breakdown of one surrogate (7-amino-1-naphthol-3-sulfonic acid) was largely due to abiotic process.

6.0 REFERENCES

Ciba Specialty Chemicals Corporation, 1998. "Composting Treatability Study Work Plan, Aerobic Composting of Toms River Soils and Selected Non-Soil Wastes", Toms River, New Jersey.

Standard Methods for the Examination of Water and Wastewater, 1992, 18th Ed. Greenberg, A. E., Clesceri, L. S., Eaton, A. D., American Public Health Association, American Water Works Association, Water Environment Federation, Washington, D. C.

USEPA, 1994. "Final Source Control Remedial Investigation Report: Ciba-Geigy Site, Toms River, New Jersey".

TABLE 3.1
Analytical Parameters and Methods
Surrogates Screening Test
Ciba-Geigy Superfund Site
Toms River, New Jersey

Analytical Parameters	Analytical Methods [1]
pH	EPA Method 150.1
Ammonia nitrogen	EPA Method 350.2
Total Kjeldahl nitrogen	EPA Method 351.2
Anions (nitrate, nitrite, orthophosphate, sulfate)	EPA Modified Method 300.0
Cations (sodium, potassium, calcium, magnesium, iron, and manganese)	Standard Methods Method 3500 [2]
Total organic carbon	EPA Method 450.1
Microbial density	Standard Methods Method 9215
VOC	EPA Method 8260
2-Aminoanthraquinone	HPLC Method [3]
7-Amino-1-napthol-3-sulfonic acid	HPLC Method
Aminoazobenzene-4-sulfonic acid	HPLC Method

Notes:
(1) The analytical parameters were analyzed by the methods listed in the table or by an equivalent method.
(2) Standard Methods for the Examination of Water and Wastewater, 1992, 18th Edition.
(3) Surrogates were analyzed by high-pressure liquid chromatography.

TABLE 3.2
Description of Treatments
Surrogates Screening Test
Ciba-Geigy Superfund Site
Toms River, New Jersey

Treatment Number	Treatment Type	Amendment with Surrogate(s)
1	Control [1]	Microcosms were amended with 2-aminoanthraquinone
2	Active	Microcosms were amended with 2-aminoanthraquinone
3	Control	Microcosms were amended with aminoazobenzene-4-sulfonic acid
4	Active	Microcosms were amended with aminoazobenzene-4-sulfonic acid
5	Control	Microcosms were amended with 7-amino-1-naphthol-3-sulfonic acid
6	Active	Microcosms were amended with 7-amino-1-naphthol-3-sulfonic acid
7	Control	Microcosms were amended with a mixture of 2-aminoanthraquinone, aminoazobenzene-4-sulfonic acid, and 7-amino-1-naphthol-3-sulfonic acid
8	Active	Microcosms were amended with a mixture of 2-aminoanthraquinone, aminoazobenzene-4-sulfonic acid, and 7-amino-1-naphthol-3-sulfonic acid

Notes:
(1) Control microcosms were treated with sodium azide to inhibit the microbial activity.

TABLE 4.1

Initial Characterization of the Groundwater and Soil [1]
Surrogate Screening Test
Ciba-Geigy Superfund Site
Toms River, New Jersey

VOC[2]	Groundwater (ug/L)
Trichloroethene	26
Tetrachloroethane	19
Chlorobenzene	46
1,1,2,2-Tetrachloroethane	116
2-Chlorotoluene	262
4-Chlorotoluene	20
1,3-Dichlorobenzene	29
1,4-Dichlorobenzene	91
1,2-Dichlorobenzene	396
1,2,4-Trichlorobenzene	1,333
1,2,3-Trichlorobenzene	46

Analytical Parameters	Soil (mg/kg)	Groundwater (mg/L)
Calcium	775	385
Iron	4,525	9
Magnesium	118	30
Manganese	9	0
Potassium	93	42
Sodium	68	201
Total Organic Carbon	1,545	35
Total Kjeldahl Nirogen	ND(<150)	ND(<0.85)
Ammonia-Nitrogen	ND(<5.2)	0
Chloride	70	600
Nitrite-Nitrogen	ND(<0.8)	ND(<0.4)
Nitrate-Nitrogen	3	5
Ortho-phosphate	ND(<3.5)	ND(<1.8)
Sulfate	34	270

Notes:
(1) Groundwater and soil were collected from the Biopilot Cell at the Site. Date obtained from the chlorobenzenes screening test was used.
(2) VOC with concentration greater than 5 ug/L are listed.
ND - Not detected (below detection limit).

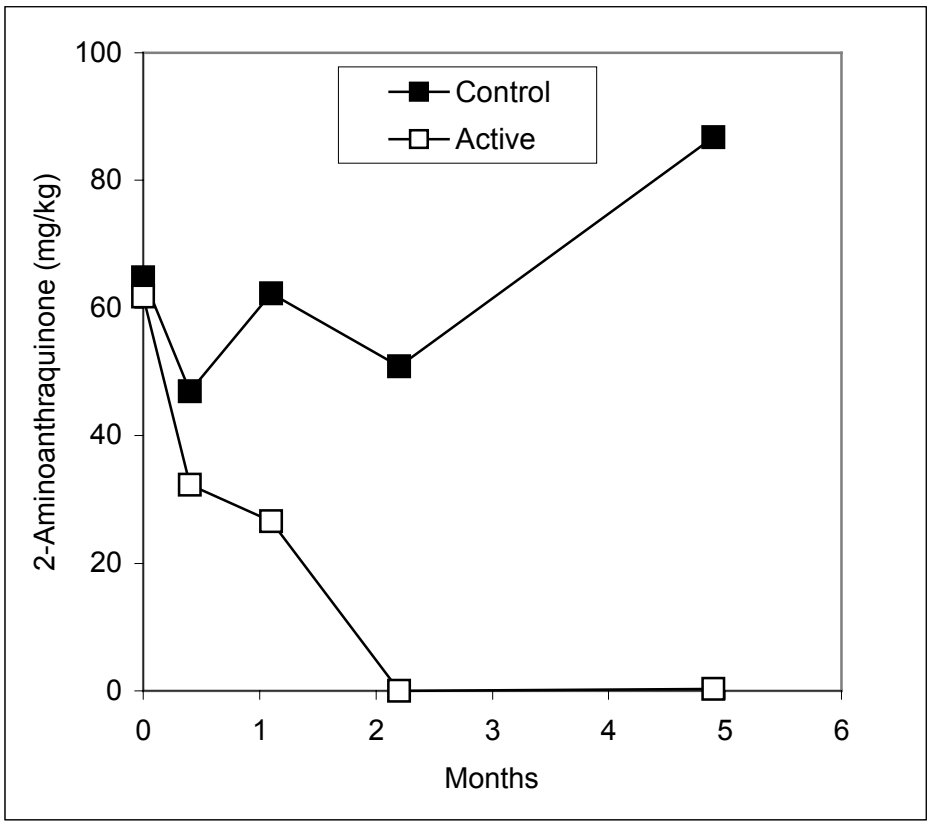
TABLE 4.2

Biodegradation of 2-Aminoanthraquinone in the Absence and Presence of Two Other Surrogates
Surrogate Screening Test
Ciba-Geigy Superfund Site
Toms River, New Jersey

Description and Surrogate	Fraction	Treatment	2-Aminoanthraquinone in Aqueous/Soil Phase					
			Month 0	Month 0.4	Month 1.1	Month 2.2	Month 3.3	Month 4.9
Microcosm amended with 2-aminoanthraquinone alone	Aqueous (mg/L)	Control	ND	ND	ND	ND	NA	ND
	Aqueous (mg/L)	Active	ND	ND	ND	0.5	ND	ND
	Soil (mg/kg)	Control	64.75	46.89	62.3	50.91	NA	86.77
	Soil (mg/kg)	Active	61.77	32.26	26.6	ND	1.43	0.27
Microcosm amended with 2-aminoanthraquinone plus other two surrogates [(1)]	Aqueous (mg/L)	Control	ND	ND	ND	ND	NA	ND
	Aqueous (mg/L)	Active	ND	ND	ND	0.61	1.1	1.2
	Soil (mg/kg)	Control	68.51	64.96	42.39	67.6	NA	73.36
	Soil (mg/kg)	Active	65.75	42.31	ND	ND	0.39	0.37

Notes:
ND - Not detected (below detection limit).
NA - Not analyzed.
(1) Two other surrogates are aminoazobenzene-4-sulfonic acid and 7-amino-1-naphthol-3-sulfonic acid.

FIGURE 4.1
Biodegradation of 2-Aminoanthraquinone
Surrogate Screening Test
Ciba-Geigy Superfund Site
Toms River, New Jersey



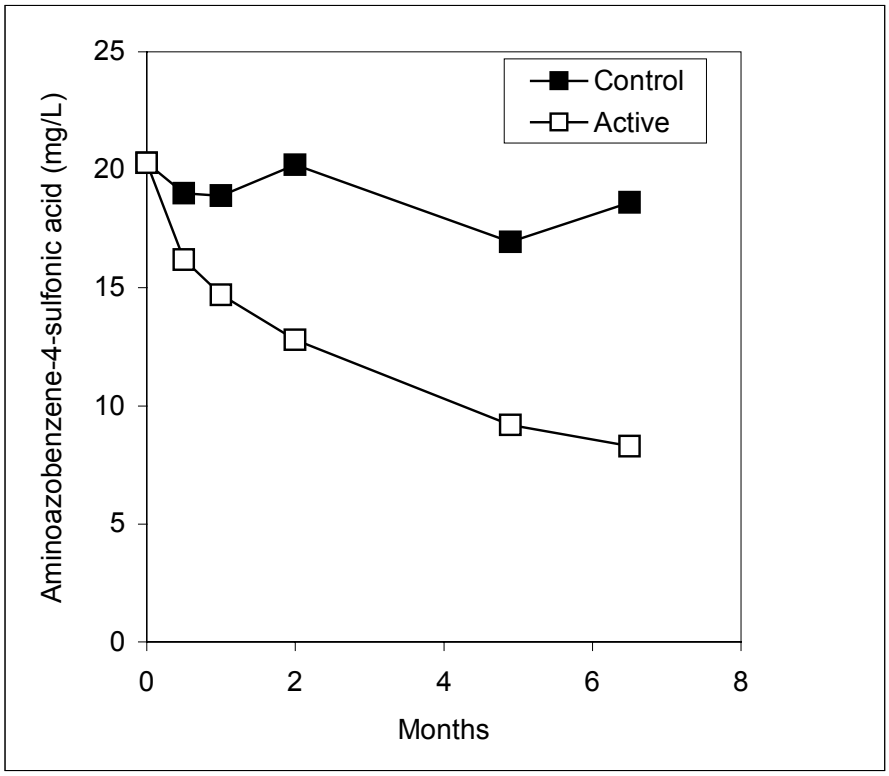
Notes:
Control - Microcosms were treated with sodium azide to inhibit the microbial activity.

TABLE 4.3
Biodegradation of Aminoazobenzene-4-Sulfonic Acid in the Absence and Presence of Two Other Surrogates
Surrogate Screening Test
Ciba-Geigy Superfund Site
Toms River, New Jeresy

Description and Surrogate	Fraction	Treatment	Aminoazobenzene-4-sulfonic acid in Aqueous/Soil Phase						
			Month 0	Month 0.4	Month 1.1	Month 2.2	Month 3.3	Month 4.9	Month 6.5
Microcosm amended with only aminoazobenzene-4-sulfonic acid	Aqueous (mg/L)	Control	20.33	18.99	18.86	20.16	NA	16.95	18.61
	Aqueous (mg/L)	Active	20.31	16.23	14.66	12.72	12.30	9.19	8.34
	Soil (mg/kg)	Control	3.01	3.20	3.81	4.22	NA	3.95	3.44
	Soil (mg/kg)	Active	1.99	2.28	3.95	3.67	3.79	2.74	2.48
Microcosm amended with aminoazobenzene-4-sulfonic acid plus other two surrogates [(1)]	Aqueous (mg/L)	Control	20.06	18.37	17.17	18.51	NA	16.10	17.04
	Aqueous (mg/L)	Active	19.93	15.74	15.21	14.70	14.04	11.26	9.58
	Soil (mg/kg)	Control	2.44	4.10	3.85	3.20	NA	3.32	4.15
	Soil (mg/kg)	Active	2.30	3.26	2.35	3.39	4.44	3.02	2.88

Notes:
NA - Not analyzed.
(1) Two other surrogates are 2-aminoanthraquinone and 7-amino-1-naphthol-3-sulfonic acid.

FIGURE 4.2
Biodegradation of Aminoazobenzene-4-Sulfonic Acid
Surrogate Screening Test
Ciba-Geigy Superfund Site
Toms River, New Jersey



Notes:
Control - Microcosms were treated with sodium azide to inhibit the microbial activity.

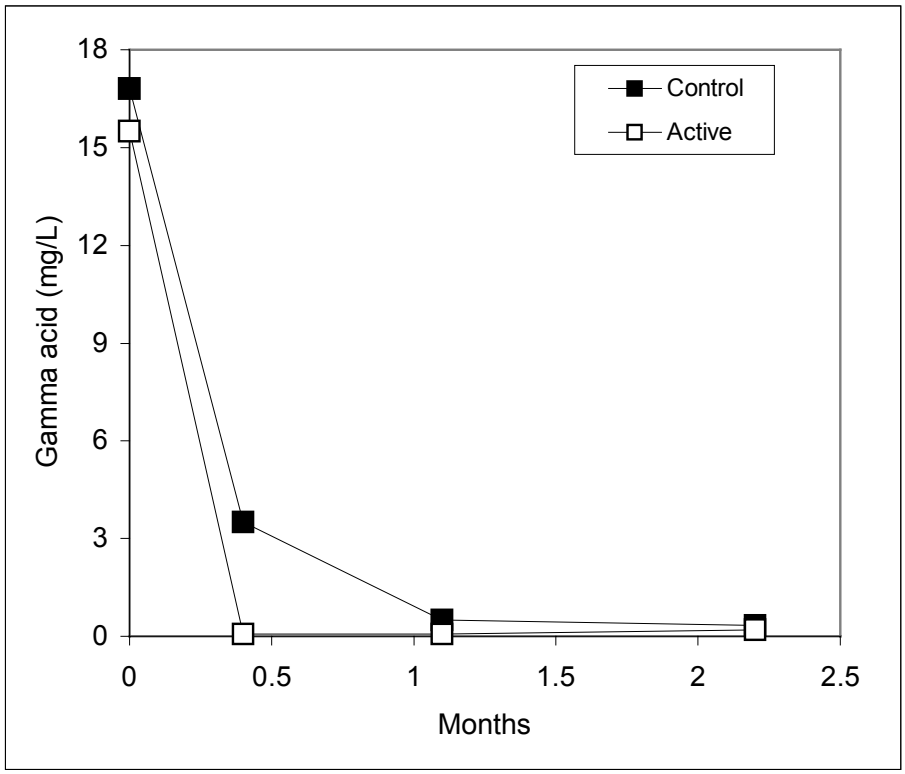
TABLE 4.4

Biodegradation of 7-Amino-1-Naphthol-3-Sulfonic Acid in the Absence and Presence of Two Other Surrogates
Surrogate Screening Test
Ciba-Geigy Superfund Site
Toms River, New Jersey

Description and Surrogate	Fraction	Treatment	7-Amino-1-Naphthol-3-Sulfonic Acid in Aqueous/Soil Phase			
			Month 0	Month 0.4	Month 1.1	Month 2.2
Microcosm amended with only 7-amino-1-naphthol-3-sulfonic acid	Aqueous (mg/L)	Control	16.78	3.46	0.44	0.33
	Aqueous (mg/L)	Active	15.50	ND	ND	0.21
	Soil (mg/kg)	Control	0.49	0.27	0.08	0.13
	Soil (mg/kg)	Active	0.04	0.04	ND	0.11
Microcosm amended with 7-amino-1-naphthol-3-sulfonic acid plus other two surrogates [1]	Aqueous (mg/L)	Control	17.35	7.16	0.51	0.25
	Aqueous (mg/L)	Active	17.69	2.47	0.71	0.26
	Soil (mg/kg)	Control	0.04	0.67	0.09	0.21
	Soil (mg/kg)	Active	ND	0.07	0.02	0.19

Notes:
ND - Not detected (below detection limit).
(1) Two other surrogates are 2-aminoanthraquinone and aminoazobenzene-4-sulfonic acid.

FIGURE 4.3
Biodegradation of 7-Amino-1-Naphthol-3-Sulfonic Acid
Surrogate Screening Test
Ciba-Geigy Superfund Site
Toms River, New Jersey



Notes:
Control - Microcosms were treated with sodium azide to inhibit the microbial activity.

TABLE 4.5
Degradation Rates and Half-Lives
Surrogate Screening Test
Ciba-Geigy Superfund Site
Toms River, New Jersey

Surrogate Compounds	Degradation Rate (/month)		Half-Life (Days)	
	Control	Active	Control	Active
2-Aminoanthraquinone	0.082	3.187	250	6
Aminoazobenzene-4-sulfonic acid	0.016	0.126	1,297	162
7-Amino-1-naphthol-3-sulfonic acid	3.148	4.355	7	5

TABLE 4.6

Changes in Nutrient, Chloride, Sulfate, and Microbial Population During the Microcosm Study
Surrogates Screening Test
Ciba-Geigy Superfund Site
Toms River, New Jersey

Parameters	Microcosms amended with 2-Aminoanthraquinone			
	Control		Active	
	Initial [1]	Month 5.5	Initial [1]	Month 5.5
Chloride (mg/L)	600	616	600	605
Sulfate (mg/L)	270	288	270	306
Total Organic Carbon (mg/L	34.6	36	34.6	18.7
Nitrate-N (mg/L)	4.6	I	4.6	27.5
Nitrite-N (mg/L)	ND(<0.4)	NA	ND(<0.4)	NA
Ortho-phosphate (mg/L)	ND(<1.8)	ND	ND(<1.8)	ND
Ammonia-N (mg/L)	0.41	34.5	0.41	1.79
Total Bacteria (CFUs/g)	12×10^3	3×10^3	42×10^4	4×10^4

Parameters	Microcosms amended with aminoazobenzene-4-sulfonic acid			
	Control		Active	
	Initial	Month 5.5	Initial	Month 5.5
Chloride (mg/L)	600	543	600	562
Sulfate (mg/L)	270	269	270	287
Total Organic Carbon (mg/L	34.6	34.7	34.6	23.6
Nitrate-N (mg/L)	4.6	I	4.6	59
Nitrite-N (mg/L)	ND(<0.4)	NA	ND(<0.4)	NA
Ortho-phosphate (mg/L)	ND(<1.8)	ND	ND(<1.8)	ND
Ammonia-N (mg/L)	0.41	34.4	0.41	3.67
Total Bacteria (CFUs/g)	12×10^3	37×10^2	18×10^3	7×10^2

Parameters	Microcosms amended with a mixture of three surrogates [2, 3]			
	Control		Active	
	Initial	Month 5.5	Initial	Month 5.5
Chloride (mg/L)	600	527	600	551
Sulfate (mg/L)	270	261	270	281
Total Organic Carbon (mg/L	34.6	39	34.6	24.3
Nitrate-N (mg/L)	4.6	I	4.6	62
Nitrite-N (mg/L)	ND(<0.4)	NA	ND(<0.4)	NA
Ortho-phosphate (mg/L)	ND(<1.8)	ND	ND(<1.8)	ND
Ammonia-N (mg/L)	0.41	34	0.41	1.82
Total Bacteria (CFUs/g)	12×10^3	5×10^3	8×10^4	14×10^4

Notes:

(1) Groundwater characteriuzation data used in the chlorobenzenes screening test was considered since the same groundwater from the Biopilot Cell was used in the surrogate screening test.

(2) The three surrogates are 2-aminoanthraquinone, aminoazobenzene-4-sulfonic acid and gamma acid.

(3) Nutrients were not analyzed in microcosms amended with gamma acid, since degradation of this surrogate was due to chemical process and not biological.

ND - Not detected (below detectgion limit).

NA - Not analzed.

I - Inference with sodium azide